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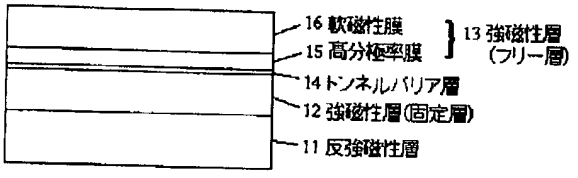
(54)【発明の名称】　磁気抵抗効果素子及びその製造方法

(57)【要約】

【課題】　磁気ヘッドや磁気メモリに必要な抵抗値及び電流密度を備え、高感度でしかも安定に信号磁界を検出できる磁気抵抗効果素子を制御よく得る。

【解決手段】　反強磁性層１１により交換結合磁界を付与した強磁性層（固定層）１２と、トンネルバリア層１４を介して薄い高分極率膜１５及び軟磁性膜１６の二層膜からなる強磁性層（フリー層）１３とで基本構造が形成されている磁気抵抗効果素子。



【特許請求の範囲】

【請求項１】強磁性層の間にトンネルバリア層を挟んだ強磁性トンネル接合の構造を有し、一方の強磁性層の外側に反強磁性層を配置した磁気抵抗効果素子において、少なくとも反強磁性層と接していない方の強磁性層がトンネルバリア層側に薄い高分極率膜を備えた軟磁性膜で構成されることを特徴とする磁気抵抗効果素子。

【請求項２】前記高分極率膜は$Co_x Fe_{1-x}$（$0 \leq x < 1$）であることを特徴とする請求項１記載の磁気抵抗効果素子。

【請求項３】前記高分極率膜は$Ni_x Fe_{1-x}$（$0 \leq x < 0.35$）であることを特徴とする請求項１記載の磁気抵抗効果素子。

【請求項４】前記高分極率膜は完全スピン分極を持つ金属間化合物であることを特徴とする請求項１記載の磁気抵抗効果素子。

【請求項５】前記金属間化合物が半金属でなることを特徴とする請求項４記載の磁気抵抗効果素子。

【請求項６】前記金属間化合物がＮｉＭｎＳｂでなることを特徴とする請求項５記載の磁気抵抗効果素子。

【請求項７】前記高分極率膜の膜厚は１０nm以下であることを特徴とする請求項１～６の何れかに記載の磁気抵抗効果素子。

【請求項８】前記軟磁性膜はパーマロイ$Ni_x Fe_{1-x}$（$0.35 \leq x \leq 0.8$）であることを特徴とする請求項１～７の何れかに記載の磁気抵抗効果素子。

【請求項９】前記トンネルバリア層はＡｌの自然酸化膜であることを特徴とする請求項１～８の何れか一項記載の磁気抵抗効果素子。

【請求項１０】前記Ａｌの膜厚は１．０～２．５nmであることを特徴とする請求項９記載の磁気抵抗効果素子。

【請求項１１】強磁性層の間にトンネルバリア層を挟んだ強磁性トンネル接合の構造を有し、一方の強磁性層がトンネルバリア層側に薄い高分極率膜を備えた軟磁性膜で構成され、もう一方の強磁性層の外側に反強磁性層を配置した磁気抵抗効果素子の製造方法において、金属または半導体からなる導電層を成膜した後、真空中に酸素を含むガスを導入し、この導電層表面を自然酸化してトンネルバリア層を形成する工程を含むことを特徴とする磁気抵抗効果素子の製造方法。

【発明の詳細な説明】

【０００１】

【発明の属する技術分野】本発明は、高密度磁気ディスク装置における再生用磁気ヘッドや高密度磁気メモリ（ＭＲＡＭ）に適した磁気抵抗効果素子に関する。

【０００２】

【従来の技術】強磁性トンネル接合は二つの強磁性層の間に数nm厚の薄い絶縁体からなるトンネルバリア層を挟んだ構造を持つ。この素子では強磁性層間に一定の電流を流した状態で強磁性層面内に外部磁界を印加した場合、両磁性層の磁化の相対角度に応じて抵抗値が変化する磁気抵抗効果現象が現れる。この磁化の向きが平行である場合には抵抗値は最小となり、反平行である場合には抵抗値が最大となる。従って、両磁性層に保磁力差を付与することによって、外部磁界の強さに応じて磁化の平行及び反平行状態を実現できるため、抵抗値の変化による磁界検出が可能となる。磁界感度を決める磁気抵抗変化率は、二つの強磁性層の分極率をP_1、P_2とすると、$2P_1P_2/(1-P_1P_2)$で表される。この式は、双方の分極率が大きいほど磁気抵抗変化率が大きくなることを意味している。

【０００３】近年、トンネルバリア層の品質の向上により、２０％という理論値に近い磁気抵抗変化率を示す強磁性トンネル接合が得られるようになったことから、磁気ヘッドや磁気メモリへの応用の可能性が高まってきた。こうした大きな磁気抵抗変化率を報告している代表例として、「１９９６年４月、ジャーナル・オブ・アプライド・フィジックス、79巻、4724～4729頁（Journal of Applied Physics,vol.79, 4724～4729,1996）」がある。

【０００４】この接合素子を図面を用いて説明する。図１２に示すように、強磁性層としてＣｏＦｅ膜１２２とＣｏ膜１２４を用い、これらの両強磁性層によってAl_2O_3からなるトンネルバリア層１２３を挟んだ構造を持つ。この構造は図１３に示すようなプロセスで作製されている。蒸着マスクを用いてガラス基板１３１上にＣｏＦｅからなる第１の強磁性層１３２を真空蒸着し（図１３（ａ））、引き続きマスクを交換して１．２～２．０nm厚のＡｌ層１３３を蒸着する（図１３（ｂ））。このＡｌ層表面を酸素グロー放電に曝すことによって、Al_2O_3からなるトンネルバリア層１３４を形成する（図１３（ｃ））。最後に、このトンネルバリア層１３４を介して第１の強磁性層１３２と長手方向が垂直に交わるようにＣｏからなる第２の強磁性層１３５を成膜して十字電極型の強磁性トンネル接合素子を完成させる（図１３（ｄ））。この方法では、磁気抵抗変化率として最大１８％という大きな値が得られている。

【０００５】その他の例として、特開平５－６３２５４号公報、特開平６－２４４４７７号公報、特開平８－７０１４８号公報、特開平８－７０１４９号公報、特開平８－３１６５４８号公報及び「１９９７年、日本応用磁気学会誌、２１巻、493～496頁」などの報告がある。ここではトンネルバリア層の形成に、Ａｌ層を成膜後、大気中に曝してAl_2O_3を成長させる方法を用いている。このように、これらの報告では図１３とはトンネルバリアの形成方法が異なるものの、強磁性層としてＦｅ、Ｃｏ、Ｎｉ及びそれらの合金からなる単層膜が使われている点は共通である。

【０００６】これらの磁気抵抗効果素子を高密度記録用の再生磁気ヘッドに適用する技術としては、スピンバル

ブに用いられている技術がある。非磁性層によって磁気的に分離された二つの強磁性層の一方に反強磁性層を重ねることによって交換結合磁界を付与して固定層とし、もう一方をフリー層とするものである。固定層の磁化の向きは媒体面と直行するように設定され、フリー層の磁化の向きは媒体面と平行に設定されている。情報を書き込んだ媒体からの漏れ磁界でフリー層の磁化の向きを変えることによって、固定層の磁化の向きとの相対角度をモジュレートし、その結果生じる素子の抵抗変化により信号検出を行う。強磁性トンネル接合が強磁性層間にトンネルバリア層を用いるのに対して、スピンバルブでは非磁性層を用いるという違いはあるものの、交換結合磁界を利用する手法は共通技術として有効であることはよく知られている。

【０００７】

【発明が解決しようとする課題】磁気抵抗効果素子を高密度磁気ヘッドに適用するためには、媒体からの漏れ磁界を高感度かつ安定に検出できなければならない。従来の強磁性トンネル接合を構成する二つの強磁性層は双方とも単層膜であり、高感度化のために大きな磁気抵抗変化率を得ようとすると大きな分極率を持つ強磁性層が必要である。しかし、こうした強磁性層は一般的に数１０Ｏｅ以上の大きな保持力を持つ。従って、交換結合磁界を利用するスピンバルブと類似の構成を用いた場合には、磁気抵抗曲線に顕著なヒステリシス特性が現れるため、安定な信号検出は困難となる。

【０００８】また、磁気抵抗効果素子を磁気ヘッドに適用するためには、熱雑音の影響を低減するために実用素子寸法である程度低い抵抗値が必要であるが、従来のトンネルバリア形成法ではその実現が困難であった。また、磁気ヘッドの高密度化には信号出力電圧の大きさが鍵を握るが、従来技術では素子特性を損なうことなく低抵抗かつ十分な高電流密度が得られないという課題もあった。さらに、従来技術ではウエーハ内やロット間の素子特性のばらつきが大きく、実用に供するだけの十分な製造歩留まりを得ることは難しかった。これらの課題は、主に従来のトンネルバリア層の形成方法に起因すると考えられる。酸素グロー放電を用いる方法では、イオンやラジカル状態の活性酸素を導電層の酸化に用いるため薄い酸化膜厚の制御すなわち素子抵抗の制御が難しいといった問題や、同時に発生する活性化された不純物ガスによってトンネルバリア層が汚染され接合品質が劣化するという問題がある。一方、大気中自然酸化による方法では、大気中の粉塵でトンネルバリア層にピンホールを生じたり、水分、炭素酸化物、窒素酸化物等の汚染を受けることによって酸素グロー放電と同様に多くの問題を抱えている。

【０００９】本発明の目的は、このような従来技術の課題を解決し、高感度でしかも安定に信号磁界を検出できる磁気抵抗効果素子を提供すること、及びこうした特性に加え、実用に必要な抵抗値及び信号出力電圧特性を備え、製造歩留まりを改善した磁気抵抗効果素子の製造方法を提供することにある。

【００１０】

【課題を解決するための手段】上記目的に従い、本発明の磁気抵抗効果素子は、強磁性層の間にトンネルバリア層を挟んだ強磁性トンネル接合の構造を有し、一方の強磁性層の外側に反強磁性層を配置した磁気抵抗効果素子において、少なくとも反強磁性層と接していない方の強磁性層がトンネルバリア層側に薄い高分極率膜を備えた軟磁性膜で構成されることを特徴とし、前記高分極率膜は$Co_x Fe_{1-x}$（$0 \leqq x < 1$）膜、又は$Ni_x Fe_{1-x}$（$0 \leqq x < 0.35$）膜、又は完全スピン分極を持つ金属間化合物であることを特徴とし、金属間化合物である場合にはＮｉＭｎＳｂなどの半金属膜であることを特徴とする。

【００１１】好ましくは、前記高分極率膜の膜厚は１０㎚以下であることを特徴とする。

【００１２】前記軟磁性膜はパーマロイ$Ni_x Fe_{1-x}$（$0.35 \leqq x \leqq 0.8$）であることを特徴とし、前記トンネルバリア層はＡｌの自然酸化膜であることを特徴とし、好ましくは、前記Ａｌの膜厚は1.0～2.5㎚であることを特徴とする。

【００１３】本発明の磁気抵抗効果素子の製造方法は強磁性層の間にトンネルバリア層を挟んだ強磁性トンネル接合の構造を有し、一方の強磁性層がトンネルバリア層側に薄い高分極率膜を備えた軟磁性膜で構成され、もう一方の強磁性層の外側に反強磁性層を配置した磁気抵抗効果素子の製造方法において、金属または半導体からなる導電層を成膜した後、真空中に酸素を含むガスを導入し、この導電層表面を自然酸化してトンネルバリア層を形成する工程を含むことを特徴とする。

【００１４】本発明においては、少なくとも反強磁性層と接していない方の強磁性層がトンネルバリア層との界面に高分極率の薄膜を備えた軟磁性膜で構成されているため、保磁力を小さく保ったまま、大きな磁気抵抗変化率が得られ、上記目的を達成できる。

【００１５】また、本発明の製造方法においては、真空中に酸素を含むガスを導入し、導電層表面を自然酸化してトンネルバリア層を形成するので、不純物ガスの影響を受けない清浄な雰囲気で熱平衡状態を保ったまま酸化層の成長が可能であり、高品質トンネルバリア層を制御よく作製することができる。

【００１６】

【発明の実施の形態】本発明の磁気抵抗効果素子に関する第１の実施の形態について、図面を参照して説明する。

【００１７】図１に示すように、反強磁性層１１／強磁性層１２の積層膜からなる固定層と強磁性層１３からなるフリー層との間にトンネルバリア層１４を挟んだ構造

を持つ磁気抵抗効果素子において、フリー層を構成する強磁性層１３がトンネルバリア層１４に接する側に薄い高分極率膜１５を備えた軟磁性膜１６で構成されている。この高分極率膜１５は一般的に軟磁性膜として用いられるパーマロイなどの薄膜に比べ保磁力が大きい。しかし、薄い高分極率膜１５を軟磁性膜１６と重ねることによって、トンネルバリア層１４と接する強磁性層13表面の分極率を大きく保ったまま保磁力を低減させることができる。強磁性トンネル接合の磁気抵抗変化率はトンネル現象に寄与する薄い強磁性層表面の性質により決まるため、こうしたフリー層構造を用いることによって大きな分極率と小さな保磁力を合わせ持つ高密度磁気ヘッドに適した磁気抵抗効果素子が得られる。一方、固定層となる強磁性層１２としては分極率の大きな材料を優先的に選べばよいが、フリー層と同様な構成にすることもできる。

【００１８】高分極率膜１５としては、$Co_x Fe_{1-x}$（$0 \leq x < 1$）、又は$Ni_x Fe_{1-x}$（$0 \leq x < 0.35$）が候補として挙げられる。完全スピン分極を持つ金属間化合物を用いる場合には薄膜としても１００％に近い分極率が得られるため、さらに大きな磁気抵抗変化率を持つ磁気抵抗効果素子が実現できる。高分極率膜１５の膜厚は１０nm以下であれば、フリー層の保磁力はほぼ軟磁性膜１６の性質で決まるため小さな値が得られるが、5nm以下であればより効果的である。軟磁性膜１６としてパーマロイ$Ni_x Fe_{1-x}$（$0.35 \leq x \leq 0.8$）を用いれば、１０e以下の小さな保持力が得られる。また、トンネルバリア層としてＡｌの自然酸化膜を選択すればピンホール密度を大幅に低減した高品質の接合が得られる。このＡｌの膜厚は厚すぎると酸化後に金属Ａｌが残ってスピン散乱の原因となり、薄すぎると下地の強磁性層の表面まで酸化されて磁気抵抗変化率の低下を引き起こすため、１．０～２．５nmであることが好ましい。この最適膜厚は下地強磁性層表面の凹凸の大きさなどの条件によって決まる。

【００１９】次に、本発明の磁気抵抗効果素子の製造方法に関する第２の実施の形態について、図面を参照して説明する。

【００２０】図２に示すように、反強磁性層２１、強磁性層（固定層）２２、導電層２３を真空中で連続成膜した後（図２（ａ））、真空を破ることなく純酸素を導入し、導電層２３の表面を自然酸化してトンネルバリア層２４を形成する（図２（ｂ））。図２（ｂ）に示すように、導電層２３は過不足無く酸化されることが望ましい。酸素を排気した後、$Co_x Fe_{1-x}$（$0 \leq x < 1$）、又は$Ni_x Fe_{1-x}$（$0 \leq x < 0.35$）、又は完全スピン分極を持つ金属間化合物からなる高分極率膜２５を成膜し、引き続き、軟磁性膜26を成膜して、強磁性トンネル接合素子の基本構造を完成させる（図２（ｃ））。

【００２１】強磁性層にＦｅ、Ｃｏ、Ｎｉまたはそれらを含む合金を用いた場合には、導電層２３として強磁性層の表面自由エネルギーより小さな値を持つＡｌを選択することにより、下地となる強磁性層２２に対して良好な被覆性を呈する。その結果、完成された素子ではピンホールによる強磁性層間の電気的ショートのない良好な特性が得られる。また、Ａｌの酸素一原子当たりの生成自由エネルギーはＦｅ、Ｃｏ、Ｎｉよりも大きいためトンネルバリア層となるAl_2O_3は接合界面で熱的に安定である。本実施の形態ではフリー層２７よりも先に固定層を成膜したが、この逆の工程でも同様な効果が得られる。

【００２２】

【実施例１】本発明の第１の実施例を図面を参照して詳細に説明する。

【００２３】本発明の磁気抵抗効果素子の基本構造は、図３に示すように、表面を熱酸化したＳｉ基板３１上に5nm厚のＴａ膜と5nm厚の$Ni_{0.81}Fe_{0.19}$膜の二層膜からなるバッファー層３２を介して形成された１５nm厚のＦｅＭｎ膜からなる反強磁性層３３と厚さ１０nmの$Ni_{0.81}Fe_{0.19}$膜からなる第１の強磁性層３４、さらにその上にAl_2O_3膜からなるトンネルバリア層３５を介して形成された厚さ3nmのＣｏＦｅ膜３６と厚さ１５nmの$Ni_{0.81}Fe_{0.19}$軟磁性膜３７の二層膜からなる第２の強磁性層３８で構成される。バッファー層３２は反強磁性的な性質を持つ面心立方構造γ相のＦｅＭｎ膜を成長させるために用いる。この構造を得るためにはバッファー層を構成する$Ni_{0.81}Fe_{0.19}$膜は（１１１）配向していることが必要であり、そのシード層としてＴａ膜を用いている。Ｔａ膜以外にもＮｂ、Ｔｉ、Ｈｆ、Ｚｒなどの他の薄膜を使っても同様な効果が得られる。本実施例では反強磁性層としてＦｅＭｎを用いているが、他にもＩｒＭｎ、ＮｉＭｎ、ＰｔＭｎ、ＰｄＭｎなどを用いることができる。第１の強磁性層３４は固定層、第２の強磁性層３８はフリー層を構成するが、この二つの層の磁化の向きは互いに直行している。

【００２４】次に、本発明の磁気抵抗効果素子の製造方法を図面を参照して詳細に説明する。

【００２５】まず、図４（ａ）に示すように表面を熱酸化したSi基板41上にＴａ膜（膜厚：5nm）と$Ni_{0.81}Fe_{0.19}$膜（膜厚：5nm）の二層膜からなるバッファー層４２、ＦｅＭｎ膜（膜厚：１５nm）からなる反強磁性層４３、$Ni_{0.81}Fe_{0.19}$膜（膜厚：１０nm）からなる第１の強磁性層４４、Ａｌ膜（膜厚：2nm）からなる導電層４５を同一真空中で連続してスパッタ蒸着した。この成膜には４インチ径のターゲット５基を備えた高周波マグネトロンスパッタ装置を用いた。スパッタ条件はすべてバックグランド圧力1×10^{-7}Ｔｏｒｒ以下、Ａｒ圧力１０mＴｏｒｒ、高周波電力２００Ｗであった。次に、スパッタ装置内に純酸素を導入し、酸素圧力

を20Torrで10分間保持して、Al導電層45を自然酸化しトンネルバリア層46を形成した（図4（b））を排気してバックグランド圧力に到達した後、CoFe膜（膜厚：3nm）47、$Ni_{0.81}Fe_{0.19}$軟磁性膜（膜厚：15nm）48からなる第2の強磁性層49、Ta膜（膜厚：5nm）からなる保護層50を連続してスパッタ蒸着し、接合構成層を完成させた（図4（c））。この保護層50は接合構成層をプロセス汚染から保護するためのものである。この接合構成層の成膜を通して、基板41面内の一方向に1000eの磁界を印加した。また、成膜後、基板41面内でこの方向と直行する方向に200eの磁界を加えた状態で一時間熱処理を行った。

【0026】次に、通常のフォトリソグラフィ技術とイオンミリング技術を用いて接合構成層の全層を、長手方向が成膜時の磁界印加の方向と一致するように下部配線形状に加工した（図4（c））。保護層50上に接合寸法を規定するためのレジストパターン51を形成し、トンネルバリア層46までイオンミリングする（図4（e））。このレジストパターンを残したままAl_2O_3膜（膜厚：250nm)からなる絶縁層52を電子ビーム蒸着した後、リフトオフを行う（図4（f））。保護層50と配線層53間の電気的な接触を得るために、露出した試料表面の逆スパッタクリーニングを行った後、Al膜（膜厚：200nm）からなる配線層53を全表面に蒸着する。次に、レジストパターンを用いて配線層53をイオンミリングし、磁気抵抗効果素子を完成させる（図4（g））。

【0027】図5に本発明の製造方法を用いて作製した磁気抵抗効果素子の代表的な磁気抵抗曲線を示す。H_{ex}は反強磁性層43と第1の強磁性層44の間の交換結合磁界の強さ、H_{c1}、H_{c2}はそれぞれフリー層及び固定層の保磁力である。磁気抵抗変化率は10．4%であり、CoFe膜47を挿入しない構造で得られた5．9%に比べ大幅に改善されている。また、フリー層の保磁力は16Oeであり、CoFe膜47を挿入しない場合と比べても10e以下の増加であった。このように、フリー層を構成する第2の強磁性層49として膜厚3nmという極薄のCoFe膜と$Ni_{0.81}Fe_{0.19}$膜の二層構成とすることにより、フリー層の保磁力を小さく保ったまま、磁気抵抗変化率を大幅に改善することができた。

【0028】一方、接合抵抗は、図6に示すように接合面積に対して精度よく逆比例の関係を示した。この傾きから、面積で規格化した抵抗値として$2．4\times10^{-6}\Omega cm^2$が得られた。磁気ヘッドなど多くのデバイス応用を可能にする、このような低抵抗値は強磁性トンネル接合構造の磁気抵抗効果素子では初めて実現した。また、抵抗値はトンネルバリア層形成時の酸素圧力及び基板温度を制御することによって、大小数桁変化させることができる。2インチSiウエーハ内の接合抵抗の最大ばらつきも±4%であり、制御性よく素子が作製できた。

【0029】図7に$10\times10\mu m^2$における磁気抵抗変化率の接合電流密度依存性を示す。磁気抵抗変化率は電流密度を増加させても10^4 A／cm^2 までは全く変化が認められなかった。3×10^4 A／cm^2 でも磁気抵抗変化率も約20%の減少に止まっている。これらの結果から、この磁気抵抗効果素子の直流信号出力電圧を求めると、10^4 A／cm^2 の電流密度で3mV、3×10^4 A／cm^2 で7mVであった。

【0030】

【実施例2】次に、本発明の第2の実施例を図面を参照して詳細に説明する。

【0031】本発明の磁気抵抗効果素子の基本構造は、図8に示すように、表面を熱酸化したSi基板81上に5nm厚のTa膜と5nm厚の$Ni_{0.81}Fe_{0.19}$膜の二層膜からなるバッファー層82を介して形成された15nm厚のFeMn膜からなる反強磁性層83と厚さ10nmのCoFe膜からなる第1の強磁性層84、さらにその上にAl_2O_3 膜からなるトンネルバリア層85を介して形成された厚さ3nmのCoFe膜86と厚さ15nmの$Ni_{0.81}Fe_{0.19}$軟磁性膜87の二層膜からなる第2の強磁性層88で構成される。

【0032】この磁気抵抗効果素子の製造方法は、第1の強磁性層として$Ni_{0.81}Fe_{0.19}$膜の代わりにCoFe膜を用いることを除いては図4のプロセスと同じである。この素子では磁気抵抗変化率は18．8%であり、第1の強磁性層として$Ni_{0.81}Fe_{0.19}$膜を用いた場合に比べ大幅に改善された。一方、フリー層の保磁力は2．0Oeと多少大きくなった。このように、フリー層を構成する第2の強磁性層88として膜厚3nmという極薄のCoFe膜と$Ni_{0.81}Fe_{0.19}$膜の二層構成とし、さらに固定層を構成する第1の強磁性層としてCoFe膜を用いることにより、フリー層の保磁力をある程度小さく保ったまま、磁気抵抗変化率を大幅に改善することができた。この磁気抵抗変化率は接合電流密度を増加させても10^4 A／cm^2 までは全く変化が認められなかった。

【0033】

【実施例3】次に、本発明の第3の実施例を図面を参照して詳細に説明する。

【0034】本発明の磁気抵抗効果素子の基本構造は、図9に示すように、表面を熱酸化したSi基板91上に5nm厚のTa膜と5nm厚の$Ni_{0.81}Fe_{0.19}$膜の二層膜からなるバッファー層92を介して形成された15nm厚のFeMn膜からなる反強磁性層93、10nm厚の$Ni_{0.81}Fe_{0.19}$軟磁性膜94と3nm厚のCoFe膜95の二層膜からなる第1の強磁性層96、さらにその上にAl_2O_3 膜からなるトンネルバリア層97を介して形成された3nm厚のCoFe膜98と15nm厚の$Ni_{0.81}Fe_{0.19}$軟磁性膜99の二層膜からなる第2の強磁性層

９１０で構成される。

【００３５】この磁気抵抗効果素子の製造方法は、第１の強磁性層として$Ni_{0.81}Fe_{0.19}$単層膜の代わりに１０nm厚の$Ni_{0.81}Fe_{0.19}$軟磁性膜９４と３nm厚のＣｏＦｅ膜９５の二層膜を用いることを除いては図４のプロセスと同じである。この素子では磁気抵抗変化率は１７．５％であり、第１の強磁性層及び第２の強磁性層として薄いＣｏＦｅ膜を挿入しない構造で得られた５．９％に比べ大幅に改善されている。また、フリー層の保磁力は１．８Ｏｅであり、ＣｏＦｅ膜を挿入しない場合と比較しても１Ｏｅ以下の増加であった。このように、固定層及びフリー層を構成する第１の強磁性層９６及び第２の強磁性層９１０として膜厚3nmという極薄のＣｏＦｅ膜と$Ni_{0.81}Fe_{0.19}$膜の二層構成とすることにより、フリー層の保磁力を小さく保ったまま、磁気抵抗変化率を大幅に改善することができた。この磁気抵抗変化率は接合電流密度を増加させても10^4　A／cm^2　までは全く変化が認められなかった。

【００３６】

【実施例４】次に、本発明の第４の実施例を図面を参照して詳細に説明する。

【００３７】本発明の磁気抵抗効果素子の基本構造は、図１０に示すように、表面を熱酸化したＳｉ基板１０１上に５nm厚のＴａ膜と５nm厚の$Ni_{0.81}Fe_{0.19}$膜の二層膜からなるバッファー層１０２を介して形成された１５nm厚のＦｅＭｎ膜からなる反強磁性層１０３と厚さ１０nmの$Ni_{0.81}Fe_{0.19}$膜からなる第１の強磁性層１０４、さらにその上にAl_2O_3　膜からなるトンネルバリア層１０５を介して形成された厚さ3nmのＦｅ膜１０６と厚さ１５nmの$Ni_{0.81}Fe_{0.19}$軟磁性膜１０７の二層膜からなる第２の強磁性層１０８で構成される。

【００３８】この磁気抵抗効果素子の製造方法は、第２の強磁性層として3nm厚のＣｏＦｅ膜と１５nm厚の$Ni_{0.81}Fe_{0.19}$軟磁性膜の二層膜の代わりに、3nm厚のＦｅ膜１０６と１５nm厚の$Ni_{0.81}Fe_{0.19}$軟磁性膜１０７の二層膜を用いることを除いては図４のプロセスと同じである。この素子では磁気抵抗変化率は１０．０％であり、Ｆｅ膜１０６を挿入しない構造で得られた５．９％に比べ大幅に改善されている。また、フリー層の保磁力は１．２Ｏｅであり、Ｆｅ膜１０６を挿入しない場合と比較しても１Ｏｅ以下の増加であった。このように、フリー層を構成する第２の強磁性層１０８として膜厚3nmという極薄のＦｅ膜と$Ni_{0.81}Fe_{0.19}$膜の二層構成とすることにより、フリー層の保磁力を小さく保ったまま、磁気抵抗変化率を大幅に改善することができた。この磁気抵抗変化率は接合電流密度を増加させても10^4　A／cm^2　までは全く変化が認められなかった。

【００３９】本実施例では固定層を構成する第１の強磁性層として$Ni_{0.81}Fe_{0.19}$膜を用いているが、その他にも実施例２及び３に示したのと同様の発想で、Ｆｅ膜、又は$Ni_{0.81}Fe_{0.19}$膜と極薄のＦｅ膜の二層膜を用いても同様の効果が得られることは言うまでもない。

【００４０】

【実施例５】次に、本発明の第５の実施例を図面を参照して詳細に説明する。

【００４１】本発明の磁気抵抗効果素子の基本構造は、図１１に示すように、表面を熱酸化したＳｉ基板１１１上に５nm厚のＴａ膜と５nm厚の$Ni_{0.81}Fe_{0.19}$膜の二層膜からなるバッファー層１１２を介して形成された１５nm厚のＦｅＭｎ膜からなる反強磁性層１１３と厚さ１０nmのＮｉＭｎＳｂ膜からなる第１の強磁性層１１４、さらにその上にＡｌ２Ｏ３膜からなるトンネルバリア層１１５を介して形成された厚さ3nmのＮｉＭｎＳｂ膜１１６と厚さ１５nmの$Ni_{0.81}Fe_{0.19}$軟磁性膜１１７の二層膜からなる第２の強磁性層１１８で構成される。

【００４２】この磁気抵抗効果素子の製造方法は、第１の強磁性層として$Ni_{0.81}Fe_{0.19}$膜の代わりにＮｉＭｎＳｂ膜を、第２の強磁性層としてＣｏＦｅ膜と$Ni_{0.81}Fe_{0.19}$軟磁性膜の二層膜の代わりに、ＮｉＭｎＳｂ膜１１６と$Ni_{0.81}Fe_{0.19}$軟磁性膜１１７の二層膜を用いることを除いては図４のプロセスと同じである。この素子では磁気抵抗変化率は２１．３％であり、第１の強磁性層として$Ni_{0.81}Fe_{0.19}$膜を用いた場合に比べ大幅に改善された。一方、フリー層の保磁力は２．６Ｏｅと多少大きくなった。このように、フリー層を構成する第２の強磁性層１１８として膜厚3nmという極薄のＮｉＭｎＳｂ膜と$Ni_{0.81}Fe_{0.19}$膜の二層構成とし、さらに固定層を構成する第１の強磁性層としてＮｉＭｎＳｂ膜を用いることにより、フリー層の保磁力をある程度小さく保ったまま、磁気抵抗変化率を大幅に改善することができた。この磁気抵抗変化率は接合電流密度を増加させても10^4　A／cm^2　までは全く変化が認められなかった。

【００４３】本実施例では固定層を構成する第一の強磁性層としてＮｉＭｎＳｂ膜を用いているが、その他にも実施例１及び３に示したのと同様の発想で、$Ni_{0.81}Fe_{0.19}$膜、または$Ni_{0.81}Fe_{0.19}$膜と極薄のＮｉＭｎＳｂ膜の二層膜を用いても同様の効果が得られることは言うまでもない。

【００４４】

【発明の効果】本発明の構造を用いれば、高感度でしかも安定に信号磁界を検出できる磁気抵抗効果素子が得られ、高密度磁気ヘッドや磁気メモリなどへの応用も可能である。また、本発明の製造方法を用いれば、デバイス応用に必要な抵抗値及び接合電流密度を備えた高品質のトンネルバリア層を制御性よく形成することができる。

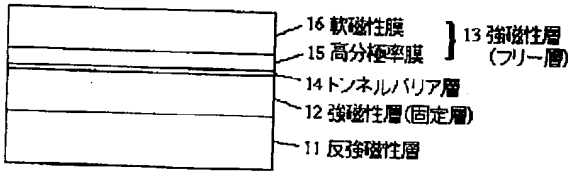
【図面の簡単な説明】

【図１】本発明の第１の実施の形態を説明するための構造図である。

【図２】（ａ）～（ｃ）は本発明の第２の実施の形態を

説明するための工程図である。
【図３】本発明の実施例１を説明するための構造図である。
【図４】（ａ）～（ｇ）は実施例１を説明するための工程図である。
【図５】実施例１で作製した磁気抵抗効果素子の磁気抵抗曲線図である。
【図６】実施例１で作製した磁気抵抗効果素子の接合抵抗と接合面積の関係を示す図である。
【図７】実施例１で作製した磁気抵抗効果素子の１０μｍ角接合における接合抵抗の電流密度依存性を示す図である。
【図８】本発明の実施例２を説明するための構造図である。
【図９】本発明の実施例３を説明するための構造図である。
【図１０】本発明の実施例４を説明するための構造図である。
【図１１】本発明の実施例５を説明するための構造図である
【図１２】従来の磁気抵抗効果素子を説明するための構造図である。
【図１３】（ａ）～（ｄ）は従来の磁気抵抗効果素子を説明するための工程図である。
【符号の説明】
１１、２１　反強磁性層
１２、２２　強磁性層（固定層）
１３、２７　強磁性層（フリー層）
１４、２４　トンネルバリア層
２５　高分極率膜
２６　軟磁性膜
２３　導電層

【図１】



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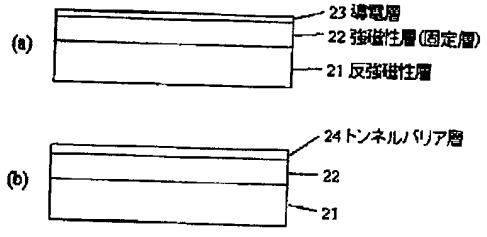

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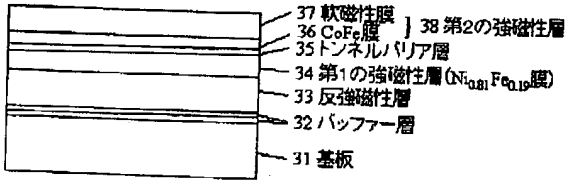

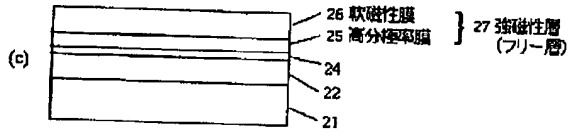

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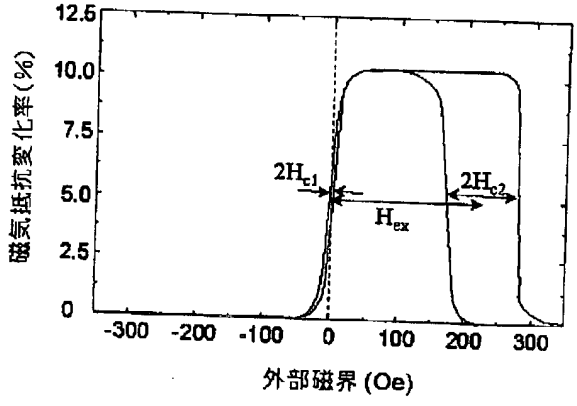

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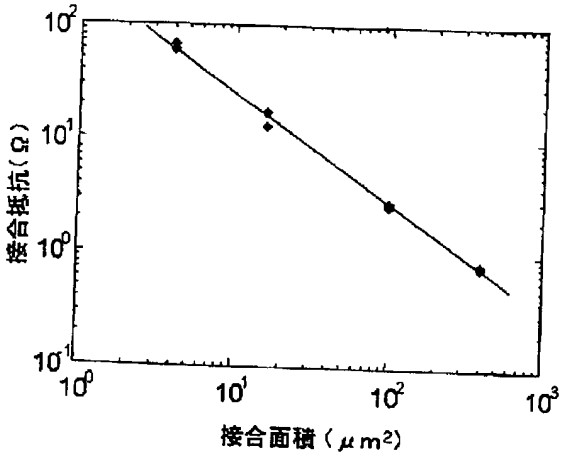

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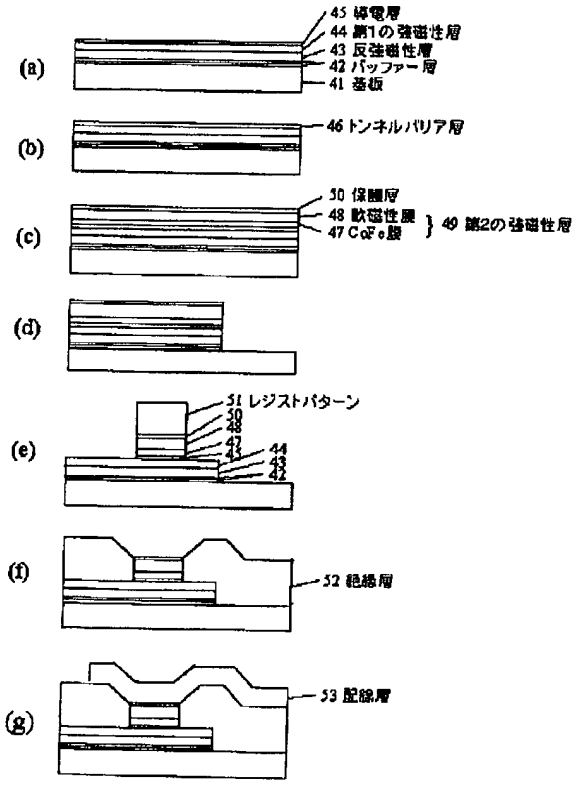

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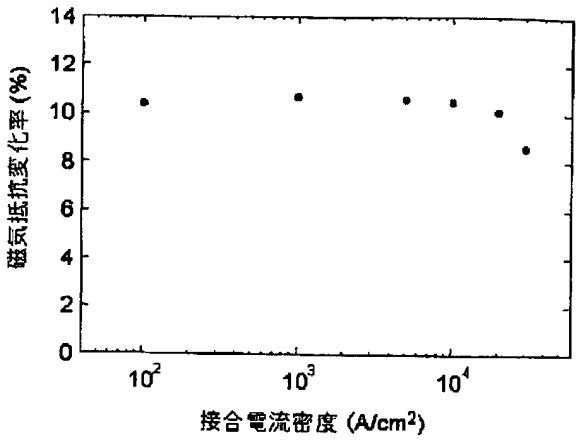

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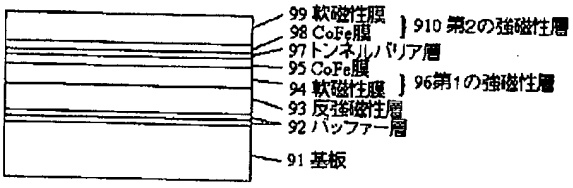

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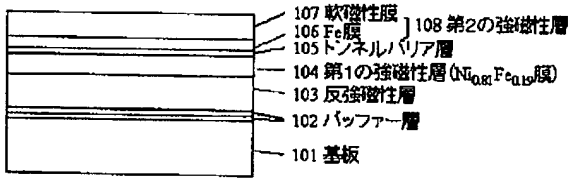

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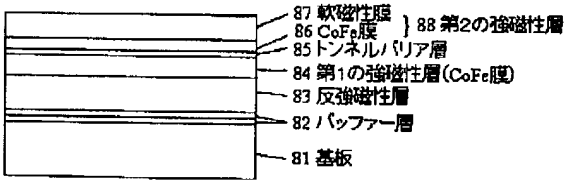

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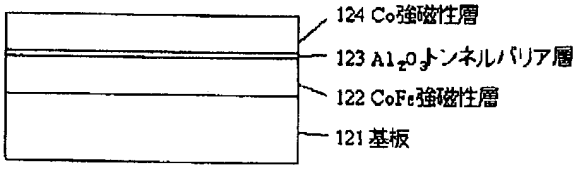

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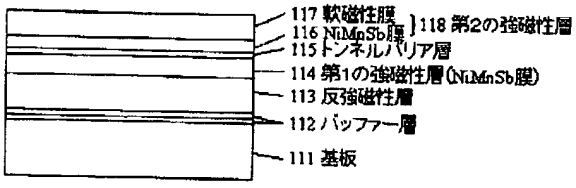

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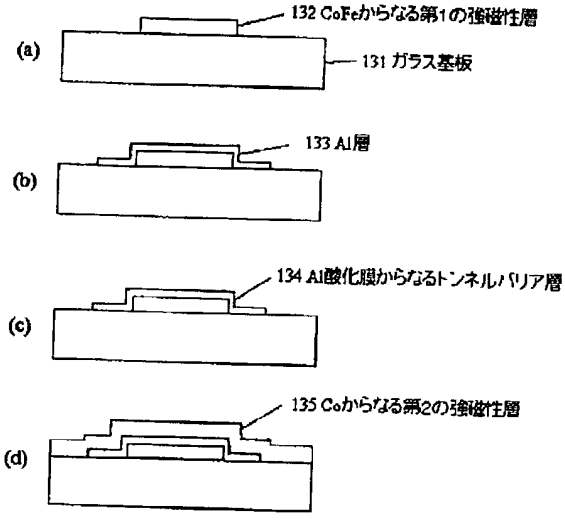
(a)
132 CoFeからなる第1の強磁性層
131 ガラス基板
(b)
133 Al層
(c)
134 Al酸化膜からなるトンネルバリア層
(d)
135 Coからなる第2の強磁性層

PATENT ABSTRACTS OF JAPAN

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H01F 10/16

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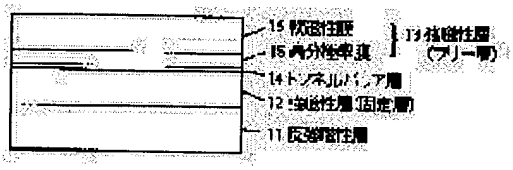
(22)Date of filing : 30.10.1997

(71)Applicant : NEC CORP
(72)Inventor : TSUGE HISANAO

(54) MAGNETO RESISTANCE EFFECT ELEMENT AND ITS MANUFACTURE

(57)Abstract:
PROBLEM TO BE SOLVED: To provide a magnet resistance effect element which has both large polarizability and a small coercive force by constituting at least one side of a ferromagnetic layer, which is not in contact with an antiferromagnetic layer of a soft magnetic film provided with a thin high-polarizability film on a tunnel barrier layer side.
SOLUTION: A ferromagnetic layer 13 constituting a free layer is constituted of a solt magnetic layer 16, provided with a thin high-polarizability film 15 on a tunnel barrier layer 14 side. The film 15 has a stronger coercive force than a thin film which is made of Permalloy (R), etc. However, the coercive force of the film 15 can be reduced, while the polarizability on the surface of the ferromagnetic layer 13 which is in contact with the tunnel barrier layer 14 is maintained at a high value. Since the magnet resistance variations of a ferromagnetic tunnel junction vary depending upon the property of the surface of thin ferromagnetic layer contribution to tunnel phenomena, the a free layer structure is adopted. Therefore, a magnetoresistance effect element having both a large polarizability and low coercive form can be realized.



LEGAL STATUS

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[Date of sending the examiner's decision of rejection] 19.10.1999
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[Date of final disposal for application]
[Patent number] 3050189
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[Number of appeal against examiner's decision of rejection] 11-17925
[Date of requesting appeal against examiner's decision of rejection] 05.11.1999
[Date of extinction of right]

* NOTICES *

1.This document has been translated by computer. So the translation may not reflect the original precisely.
2.**** shows the word which can not be translated.
3.In the drawings, any words are not translated.

CLAIMS

[Claim(s)]
[Claim 1] A magneto-resistive effect element characterized by consisting of soft magnetism films by which a ferromagnetic layer of a direction which is not in contact with an antiferromagnetism layer at least equipped a tunnel barrier layer side with a thin high polarizability film in a magneto-resistive effect element which has structure of a ferromagnetic tunnel junction whose tunnel barrier layer was pinched between ferromagnetic layers, and has arranged an antiferromagnetism layer on the outside of one ferromagnetic layer.
[Claim 2] said high polarizability film -- Cox Fe 1-x (0<=x<1) it is -- a magneto-resistive effect element according to claim 1 characterized by things.
[Claim 3] said high polarizability film -- Nix Fe 1-x (0<=x<0.35) it is -- a magneto-resistive effect element according to claim 1 characterized by things.
[Claim 4] Said high polarizability film is a magneto-resistive effect element according to claim 1 characterized by being an intermetallic compound with perfect spin polarization.
[Claim 5] A magneto-resistive effect element according to claim 4 characterized by said intermetallic compound becoming with semimetal.
[Claim 6] A magneto-resistive effect element according to claim 5 characterized by said intermetallic compound becoming by NiMnSb.
[Claim 7] Thickness of said high polarizability film is a magneto-resistive effect element given in any of claims 1-6 characterized by being 10nm or less they are.
[Claim 8] said soft magnetism film -- a permalloy Nix Fe 1-x (0.35<=x<=0.8) it is -- a magneto-resistive effect element given in any of claims 1-7 characterized by things they are.
[Claim 9] Said tunnel barrier layer is the magneto-resistive effect element of claim 1-8 characterized by being the natural oxidation film of aluminum given in any 1 term.
[Claim 10] Thickness of said aluminum is a magneto-resistive effect element according to claim 9 characterized by being 1.0-2.5nm.
[Claim 11] It has structure of a ferromagnetic tunnel junction whose tunnel barrier layer was pinched between ferromagnetic layers. In a manufacture method of a magneto-resistive effect element that one ferromagnetic layer consisted of soft magnetism films which equipped a tunnel barrier layer side with a thin high polarizability film, and has arranged an antiferromagnetism layer on the outside of another ferromagnetic layer A manufacture method of a magneto-resistive effect element characterized by including a process which introduces gas containing oxygen, carries out natural oxidation of this conductive layer front face, and forms a tunnel barrier layer into a vacuum after forming a conductive layer which consists of a metal or a semiconductor.

[Translation done.]

* NOTICES *

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[The technical field to which invention belongs] This invention relates to the magneto-resistive effect element suitable for the magnetic head for playback and high density MAG memory (MRAM) in a high density magnetic disk drive.
[0002]
[Description of the Prior Art] A ferromagnetic tunnel junction has the structure whose tunnel barrier layer which consists of a thin insulating material of several nm thickness was pinched between two ferromagnetic layers. With this element, where fixed current is passed between ferromagnetic layers, when an external magnetic field is impressed in a ferromagnetic stratification plane, the magneto-resistive effect phenomenon in which resistance changes according to whenever [angular relation / of magnetization of both magnetic layers] appears. When the sense of this magnetization is parallel, resistance serves as min, and in being anti-parallel, resistance serves as max. Therefore, since parallel of magnetization and an anti-parallel condition are realizable by giving a coercive force difference to both magnetic layers according to the strength of an external magnetic field, the magnetic field detection by the resistance value change is attained. The magnetic-reluctance rate of change which determines magnetic field sensitivity is the polarizability of two ferromagnetic layers P1 and P2 It is expressed with 2P1 P2/(1-P1 P2) when it carries out. This formula means that magnetic-reluctance rate of change becomes large, so that both polarizability is large.
[0003] Since the ferromagnetic tunnel junction which shows the magnetic-reluctance rate of change near the theoretical value of 20% by improvement in the quality of a tunnel barrier layer came to be obtained in recent years, the application possibility to the magnetic head or magnetic memory has increased. As an example of representation which has reported such big magnetic-reluctance rate of change, there are "April, 1996, journal OBU applied physics, 79 volumes, and 4724-4729 pages (4729 79 Journal of Applied Physics, vol. 4724- 1996)."
[0004] This cementation element is explained using a drawing. it is shown in drawing 12 -- as -- as a ferromagnetic layer -- the CoFe film 122 and the Co film 124 -- using -- both these ferromagnetism layers -- aluminum203 from -- it has the structure whose becoming tunnel barrier layer 123 was pinched. This structure is produced in the process as shown in drawing 13 . Vacuum deposition of the 1st ferromagnetic layer 132 which consists of CoFe on a glass substrate 131 using a vacuum evaporationo mask is carried out (drawing 13 (a)), masks are exchanged succeedingly, and the aluminum layer 133 of 1.2-2.0nm thickness is vapor-deposited (drawing 13 (b)). By putting this aluminum layer front face to oxygen glow discharge, it is aluminum2. The tunnel barrier layer 134 which consists of 03 is formed (drawing 13 (c)). The 2nd ferromagnetic layer 135 which finally consists of Co so that the 1st ferromagnetic layer 132 and longitudinal direction may cross vertically through this tunnel barrier layer 134 is formed, and the ferromagnetic tunnel junction element of a cross-joint electrode mold is completed (drawing 13 (d)). By this method, the big value of a maximum of 18% is acquired as magnetic-reluctance rate of change.
[0005] As other examples, there is a report of JP,5-63254,A, JP,6-244477,A, JP,8-70148,A, JP,8-70149,A, JP,8-316548,A, "1997, the Magnetics Society of Japan, 21 volumes, 493-496 etc. pages", etc., etc. It puts to formation of a tunnel barrier layer into [after forming aluminum layer] atmospheric air here, and is aluminum2. 03 The method of making it growing up is used. Thus, although the formation method of the tunnel barrier differs from drawing 13 , the point that the monolayer which consists of Fe, Co, nickel, and those alloys as a ferromagnetic layer is used is common to these reports.
[0006] There is technology used for the spin bulb as technology which applies these magneto-resistive effect elements to the playback magnetic head for high density record. By putting an antiferromagnetism layer on one side of two ferromagnetic layers magnetically separated by the non-magnetic layer, a switched connection magnetic field is given, consider as the fixed bed, and let another side be a free layer. The sense of magnetization of the fixed bed is set up so

that it may go direct with a data-medium side, and the sense of magnetization of a free layer is set as a data-medium side and parallel. By changing the sense of magnetization of a free layer by the leakage magnetic field from data medium which wrote in information, whenever [with the sense of magnetization of the fixed bed / angular relation] is modulated, and resistance change of the element produced as a result performs signal detection. It is well known for the spin bulb to a ferromagnetic tunnel junction using a tunnel barrier layer between ferromagnetic layers that the technique for which difference of using a non-magnetic layer uses the switched connection magnetic field of a certain thing is effective as common technology. [0007]

[Problem(s) to be Solved by the Invention] In order to apply a magneto-resistive effect element to the high density magnetic head, the leakage magnetic field from data medium must be detectable to high sensitivity and stability. If both sides are monolayer and are going to acquire the big magnetic-reluctance rate of change for high-sensitivity-izing, a ferromagnetic layer with big polarizability is required for two ferromagnetic layers which constitute the conventional ferromagnetic tunnel junction. However, generally such a ferromagnetic layer is several 10. It has the big holding power more than Oe. Therefore, since a hysteresis characteristic remarkable in a magnetic-reluctance curve appears when the configuration of the spin bulb using a switched connection magnetic field and resemblance is used, stable signal detection becomes difficult.

[0008] moreover, the degree which is a practical use element size in order to apply a magneto-resistive effect element to the magnetic head, and to reduce the effect of thermal noise -- although low resistance was required, by the conventional tunnel barrier forming method, the implementation was difficult. Moreover, although the magnitude of signal output voltage grasped the key for the densification of the magnetic head, with the conventional technology, the technical problem that low resistance and sufficient high current density were not obtained also occurred, without spoiling an element property. Furthermore, it was difficult for dispersion in the inside of a wafer or a lot-to-lot element property to be large, and to obtain sufficient manufacture yield with which practical use is presented with the conventional technology. It is thought that these technical problems mainly originate in the formation method of the conventional tunnel barrier layer. By the method using oxygen glow discharge, in order to use the active oxygen of ion or a radical condition for oxidation of a conductive layer, there are a problem that control of thin oxide-film thickness, i.e., control of element resistance, is difficult, and a problem that a tunnel barrier layer is polluted and cementation quality deteriorates by the activated impurity gas which occurs simultaneously. On the other hand, by the method by the natural oxidation in atmospheric air, it has many problems like oxygen glow discharge by producing a pinhole in a tunnel barrier layer, or receiving contamination of moisture, a carbon oxide, nitrogen oxides, etc. with the dust in atmospheric air.

[0009] The object of this invention solves the technical problem of such conventional technology, in addition to offering the magneto-resistive effect element which can moreover detect a signal magnetic field to stability by high sensitivity, and such a property, is equipped with resistance required for practical use, and a signal output voltage property, and is to offer the manufacture method of a magneto-resistive effect element of having improved the manufacture yield.

[0010]

[Means for Solving the Problem] The above-mentioned object is followed. A magneto-resistive effect element of this invention In a magneto-resistive effect element which has structure of a ferromagnetic tunnel junction whose tunnel barrier layer was pinched between ferromagnetic layers, and has arranged an antiferromagnetism layer on the outside of one ferromagnetic layer It is characterized by consisting of soft magnetism films by which a ferromagnetic layer of a direction which is not in contact with an antiferromagnetism layer at least equipped a tunnel barrier layer side with a thin high polarizability film. Said high polarizability film is Cox. Fe 1-x (0<=x<1) It is characterized by being a film, 1-Nix Fex (0<=x<0.35) film, or an intermetallic compound with perfect spin polarization, and when it is an intermetallic compound, it is characterized by being semimetal films, such as NiMnSb.

[0011] Preferably, thickness of said high polarizability film is characterized by being 10nm or less.

[0012] It is characterized by said soft magnetism film being Permalloy Nix Fe 1-x (0.35<=x<=0.8), and is characterized by said tunnel barrier layer being the natural oxidation film of aluminum, and thickness of said aluminum is preferably characterized by being 1.0-2.5nm.

[0013] A manufacture method of a magneto-resistive effect element of this invention has structure of a ferromagnetic tunnel junction whose tunnel barrier layer was pinched between ferromagnetic layers. In a manufacture method of a magneto-resistive effect element that one ferromagnetic layer consisted of soft magnetism films which equipped a tunnel barrier layer side with a thin high polarizability film, and has arranged an antiferromagnetism layer on the outside of another ferromagnetic layer After forming a conductive layer which consists of a metal or a semiconductor, it is characterized by including a process which introduces gas containing oxygen, carries out natural oxidation of this conductive layer front face, and forms a tunnel barrier layer into a vacuum.

[0014] In this invention, keeping coercive force small, since a ferromagnetic layer of a direction which is not in contact with an antiferromagnetism layer at least consists of soft magnetism films which equipped an interface with a tunnel barrier layer with a thin film of a rate of the hyperpolarization, big magnetic-reluctance rate of change is acquired, and the above-mentioned object can be attained.

[0015] Moreover, in a manufacture method of this invention, since gas containing oxygen is introduced, natural oxidation of the conductive layer front face is carried out and a tunnel barrier layer is formed into a vacuum, maintaining a thermal equilibrium state in a pure ambient atmosphere which is not influenced of impurity gas, growth of an oxidation zone is possible and a high quality tunnel barrier layer can be produced with sufficient control.

[0016]

[Embodiment of the Invention] The gestalt of the 1st operation about the magneto-resistive effect element of this invention is explained with reference to a drawing.

[0017] In the magneto-resistive effect element with the structure whose tunnel barrier layer 14 was pinched between the free layers which consist of the fixed bed which consists of a cascade screen of the 11/ferromagnetism layer 12 of antiferromagnetism layers, and a ferromagnetic layer 13 as shown in drawing 1 , the ferromagnetic layer 13 which constitutes a free layer consists of soft magnetism films 16 which equipped with the thin high polarizability film 15 the side which touches the tunnel barrier layer 14. This high polarizability film 15 has large coercive force compared with thin films, such as a permalloy generally used as a soft magnetism film. However, coercive force can be reduced by piling up the thin high polarizability film 15 with the soft magnetism film 16, keeping large the polarizability of ferromagnetic layer 13 front face which touches the tunnel barrier layer 14. Since the magnetic-reluctance rate of change of a ferromagnetic tunnel junction is decided by the property of the thin ferromagnetic layer front face which contributes to tunneling, the magneto-resistive effect element suitable for the high density magnetic head having big polarizability and small coercive force is obtained by using such a free layer system. Although what is necessary is just to choose preferentially the material with polarizability big on the other hand as a ferromagnetic layer 12 used as the fixed bed, it can also be made the same configuration as a free layer.

[0018] As a high polarizability film 15, it is Cox Fe 1-x. (0<=x<1) Or Nix Fe 1-x (0<=x<0.35) It is mentioned as a candidate. Since the polarizability near 100% also as a thin film is obtained when using an intermetallic compound with perfect spin polarization, a magneto-resistive effect element with still bigger magnetic-reluctance rate of change is realizable. If the thickness of the high polarizability film 15 is 10nm or less, since the coercive force of a free layer is mostly decided by the property of the soft magnetism film 16, a small value will be acquired, but it is more effective if it is 5nm or less. If Permalloy Nix Fe 1-x (0.35<=x<=0.8) is used as a soft magnetism film 16, the small holding power of 1 or less Oe will be acquired. Moreover, if the natural oxidation film of aluminum is chosen as a tunnel barrier layer, cementation of the high quality which reduced pinhole density substantially will be acquired. In order Metal aluminum will remain after oxidation and to become the cause of spin dispersion, if the thickness of this aluminum is too thick, to oxidize to the front face of the ferromagnetic layer of a substrate if too thin, and to cause decline in magnetic-reluctance rate of change, it is desirable that it is 1.0-2.5nm. This optimal thickness is decided by conditions, such as magnitude of the irregularity of a substrate ferromagnetism layer front face.

[0019] Next, the gestalt of the 2nd operation about the manufacture method of the magneto-resistive effect element of this invention is explained with reference to a drawing.

[0020] As shown in drawing 2 , after carrying out continuation membrane formation of the antiferromagnetism layer 21, the ferromagnetic layer (fixed bed) 22, and the conductive layer 23 in a vacuum (drawing 2 (a)), pure oxygen is introduced without breaking a vacuum, natural oxidation of the front face of a conductive layer 23 is carried out, and the tunnel barrier layer 24 is formed (drawing 2 (b)). As shown in drawing 2 (b), as for a conductive layer 23, oxidizing without excess and deficiency is desirable. After exhausting oxygen, Cox Fe 1-x (0<=x<1), Nix Fe 1-x (0<=x<0.35), or the high polarizability film 25 that consists of an intermetallic compound with perfect spin polarization is formed, succeedingly, the soft magnetism film 26 is formed and the basic structure of a ferromagnetic tunnel junction element is completed (drawing 2 (c)).

[0021] When the alloy which contains Fe, Co, nickel, or them in a ferromagnetic layer is used, good coat nature is presented to the ferromagnetic layer 22 used as a substrate by choosing aluminum with the value smaller than the surface free energy of a ferromagnetic layer as a conductive layer 23. Consequently, with the completed element, the good property that no electric short circuit between the ferromagnetic layers by the pinhole is is acquired. Moreover, the free energy of formation per oxygen 1 atom of aluminum is aluminum2 which serves as a tunnel barrier layer since it is larger than Fe, Co, and nickel. 03 It is thermally stable at a cementation interface. Although the fixed bed was formed ahead of the free layer 27 with the gestalt of this operation, the same effect is acquired also at the process of this reverse.

[0022]
[Example 1] The 1st example of this invention is explained to details with reference to a drawing.
[0023] As the basic structure of the magneto-resistive effect element of this invention is shown in drawing 3 The buffer layer 32 which consists of a bilayer film of Ta film of 5nm thickness and nickel0.81Fe0.19 film of 5nm thickness is minded on the Si substrate 31 which oxidized the front face thermally. It is aluminum2 on it to the 1st ferromagnetic layer 34 and pan which consist of nickel0.81Fe0.19 film with an antiferromagnetism layer [33] and a thickness of 10nm which consists of a FeMn film of formed 15nm thickness. 03 The tunnel barrier layer 35 which consists of a film is minded. It consists of the 2nd ferromagnetic layer 38 which consists of a formed bilayer film of the CoFe film 36 with a thickness of 3nm and the nickel0.81Fe0.19 soft-magnetism film 37 with a thickness of 15nm. The buffer layer 32 is used in order to grow up the FeMn film of a face centered cubic structure gamma phase with an antiferromagnetism-property. In order to acquire this structure, nickel0.81Fe0.19 film which constitutes a buffer layer needs to carry out orientation (111), and uses Ta film as that seed layer. The same effect is acquired even if it uses other thin films, such as Nb, Ti, Hf, and Zr, besides Ta film. Although FeMn is used as an antiferromagnetism layer in this example, IrMn, NiMn, PtMn, PdMn, etc. can be used for others. Although the fixed bed and the 2nd ferromagnetic layer 38 constitute a free layer in the 1st ferromagnetic layer 34, the sense of magnetization of these two layers has gone direct mutually.
[0024] Next, the manufacture method of the magneto-resistive effect element of this invention is explained to details with reference to a drawing.
[0025] first As shown in drawing 4 (a), a front face On the Si substrate 41 oxidized thermally, Ta film (thickness : 5nm) and nickel0.81Fe0.19 film (thickness: Buffer layer 42 which consists of a bilayer film of 5nm) Antiferromagnetism layer 43 which consists of a FeMn film (thickness: 15nm) The 1st ferromagnetic layer 44 which consists of nickel0.81Fe0.19 film (thickness: 10nm), and the conductive layer 45 which consists of an aluminum film (thickness: 2nm) Spatter vacuum evaporationo was continuously carried out in the same vacuum. RF magnetron sputtering equipment equipped with five targets of a 4 inch diameter was used for this membrane formation. All spatter conditions were 1x10 to 7 or less Torrs of background pressures, Ar pressure 10mTorr, and high-frequency power 200W. Next, introduce pure oxygen in a sputtering system and the oxygen pressure force is held for 10 minutes by 20Torr(s). Natural oxidation of the aluminum conductive layer 45 was carried out, and the tunnel barrier layer 46 was formed (after exhausting drawing 4 (b) and reaching a background pressure). The spatter vacuum evaporationo of the 2nd ferromagnetic layer 49 which consists of a CoFe film (thickness: 3nm) 47 and a nickel0.81Fe0.19 soft-magnetism film (thickness: 15nm) 48, and the protective layer 50 which consists of a Ta film (thickness: 5nm) was carried out continuously, and the cementation configuration layer was completed (drawing 4 (c)). This protective layer 50 is for protecting a cementation configuration layer from process contamination. The magnetic field of 100Oe(s) was impressed to the one direction in the 41st page of a substrate through membrane formation of this cementation configuration layer. Moreover, where the magnetic field of 200Oe(s) is added in this direction and the direction which goes direct after membrane formation and within the 41st page of a substrate, heat treatment was performed for 1 hour.
[0026] Next, the lower wiring configuration was processed so that it might be in agreement with the direction of a longitudinal direction's magnetic field impression at the time of membrane formation of all the layers of a cementation configuration layer using usual photolithography technology and ion milling technology (drawing 4 (c).). The resist pattern 51 for specifying a cementation size is formed on a protective layer 50, and ion milling is carried out to the tunnel barrier layer 46 (drawing 4 (e)). A lift off is performed after carrying out electron beam evaporation of the insulating layer 52 which consists of an aluminum2 film (thickness: 250nm), with this resist pattern left. 03 (drawing 4 (f).) In order to acquire the electric contact between a protective layer 50 and a wiring layer 53, after performing reverse spatter cleaning on the exposed front face of a sample, the wiring layer 53 which consists of an aluminum film (thickness: 200nm) is vapor-deposited on all front faces. Next, ion milling of the wiring layer 53 is carried out using a resist pattern, and a magneto-resistive effect element is completed (drawing 4 (g)).
[0027] The typical magnetic-reluctance curve of the magneto-resistive effect element which used and produced the manufacture method of this invention to drawing 5 is shown. Hex is Hc1 and the switched connection magnetic field strength between the antiferromagnetism layer 43 and the 1st ferromagnetic layer 44 and Hc2 are the coercive force of a free layer and the fixed bed, respectively. Magnetic-reluctance rate of change is 10.4%, and improves substantially compared with 5.9% obtained with the structure which does not insert the CoFe film 47. Moreover, the coercive force of a free layer was 16Oe(s), and even if it measured it against the case where the CoFe film 47 is not inserted, it was the increment in 1 or less Oe. Thus, magnetic-reluctance rate of change has been improved substantially, keeping the coercive force of a free layer small as 2nd ferromagnetic layer 49 which constitutes a free layer by considering as a bilayer configuration of an ultra-thin CoFe film and nickel0.81Fe0.19 film called 3nm of thickness.
[0028] On the other hand, the bond resistance showed the relation of reverse proportion with a sufficient precision to the

plane-of-composition product, as shown in drawing 6 . 2.4x10-6ohmcm2 was obtained from this inclination as resistance standardized in area. Such low resistance that enables many device application, such as the magnetic head, was realized for the first time with the magneto-resistive effect element of ferromagnetic tunnel junction structure. Moreover, resistance can be changed several figures size by controlling the oxygen pressure force and substrate temperature at the time of the tunnel barrier stratification. The maximum dispersion of the bond resistance in a 2 inch Si wafer is also **4%, and has produced the element with the sufficient controllability.

[0029] 10x10 micrometers of cementation current density dependencies of the magnetic-reluctance rate of change in 2 are shown in drawing 7 . even if magnetic-reluctance rate of change makes current density increase -- 104 A/cm2 ****** -- private seals were completely changeless. 3x104 A/cm2 But magnetic-reluctance rate of change has also stopped at about 20% of reduction. It is 104 when it asks for the direct current signal output voltage of this magneto-resistive effect element from these results. A/cm2 It is 3mV and 3x104 at current density. A/cm2 It was 7mV.

[0030]

[Example 2] Next, the 2nd example of this invention is explained to details with reference to a drawing.

[0031] As the basic structure of the magneto-resistive effect element of this invention is shown in drawing 8 The buffer layer 82 which consists of a bilayer film of Ta film of 5nm thickness and nickel0.81Fe0.19 film of 5nm thickness is minded on the Si substrate 81 which oxidized the front face thermally. It is aluminum2 on it to the 1st ferromagnetic layer 84 and pan which consist of a CoFe film with an antiferromagnetism layer [83] and a thickness of 10nm which consists of a FeMn film of formed 15nm thickness. 03 The tunnel barrier layer 85 which consists of a film is minded. It consists of the 2nd ferromagnetic layer 88 which consists of a formed bilayer film of the CoFe film 86 with a thickness of 3nm and the nickel0.81Fe0.19 soft-magnetism film 87 with a thickness of 15nm.

[0032] If the manufacture method of this magneto-resistive effect element removes using a CoFe film instead of nickel0.81Fe0.19 film as 1st ferromagnetic layer, it is the same as the process of drawing 4 . With this element, magnetic-reluctance rate of change is 18.8%, and has improved substantially compared with the case where nickel0.81Fe0.19 film is used as 1st ferromagnetic layer. On the other hand, the coercive force of a free layer became large somewhat with 2.0Oe(s). Thus, magnetic-reluctance rate of change has been improved substantially, keeping the coercive force of a free layer to some extent small as 2nd ferromagnetic layer 88 which constitutes a free layer by considering as a bilayer configuration of an ultra-thin CoFe film and nickel0.81Fe0.19 film called 3nm of thickness, and using a CoFe film as 1st ferromagnetic layer which constitutes the fixed bed further. even if this magnetic-reluctance rate of change makes cementation current density increase -- 104 A/cm2 ****** -- private seals were completely changeless.

[0033]

[Example 3] Next, the 3rd example of this invention is explained to details with reference to a drawing.

[0034] As the basic structure of the magneto-resistive effect element of this invention is shown in drawing 9 The buffer layer 92 which consists of a bilayer film of Ta film of 5nm thickness and nickel0.81Fe0.19 film of 5nm thickness is minded on the Si substrate 91 which oxidized the front face thermally. It is aluminum2 on it to the 1st ferromagnetic layer 96 and pan which consist of a bilayer film of the nickel0.81Fe0.19 soft-magnetism film 94 of 93 or 10nm thickness of antiferromagnetism layers, and the CoFe film 95 of 3nm thickness which consists of a FeMn film of formed 15nm thickness. 03 The tunnel barrier layer 97 which consists of a film is minded. It consists of the 2nd ferromagnetic layer 910 which consists of a formed bilayer film of the CoFe film 98 of 3nm thickness, and the nickel0.81Fe0.19 soft-magnetism film 99 of 15nm thickness.

[0035] If the manufacture method of this magneto-resistive effect element removes using the bilayer film of the nickel0.81Fe0.19 soft-magnetism film 94 of 10nm thickness, and the CoFe film 95 of 3nm thickness instead of nickel0.81Fe0.19 monolayer as 1st ferromagnetic layer, it is the same as the process of drawing 4 . With this element, magnetic-reluctance rate of change is 17.5%, and improves substantially compared with 5.9% obtained with the structure which does not insert a CoFe film thin as the 1st ferromagnetic layer and 2nd ferromagnetic layer. Moreover, the coercive force of a free layer was 1.8Oe(s), and even if it measured it with the case where a CoFe film is not inserted, it was the increment in 1 or less Oe. Thus, magnetic-reluctance rate of change has been improved substantially, keeping the coercive force of a free layer small by considering as a bilayer configuration of an ultra-thin CoFe film and nickel0.81Fe0.19 film called 3nm of thickness as the 1st ferromagnetic layer 96 which constitutes the fixed bed and a free layer, and 2nd ferromagnetic layer 910. even if this magnetic-reluctance rate of change makes cementation current density increase -- 104 A/cm2 ****** -- private seals were completely changeless.

[0036]

[Example 4] Next, the 4th example of this invention is explained to details with reference to a drawing.

[0037] As the basic structure of the magneto-resistive effect element of this invention is shown in drawing 10 The buffer

layer 102 which consists of a bilayer film of Ta film of 5nm thickness and nickel0.81Fe0.19 film of 5nm thickness is minded on the Si substrate 101 which oxidized the front face thermally. It is aluminum on it to the 1st ferromagnetic layer 104 and pan which consist of nickel0.81Fe0.19 film with an antiferromagnetism layer [103] and a thickness of 10nm which consists of a FeMn film of formed 15nm thickness. 203 The tunnel barrier layer 105 which consists of a film is minded. It consists of the 2nd ferromagnetic layer 108 which consists of a formed bilayer film of the Fe film 106 with a thickness of 3nm and the nickel0.81Fe0.19 soft-magnetism film 107 with a thickness of 15nm.

[0038] If the manufacture method of this magneto-resistive effect element removes using the bilayer film of the Fe film 106 of 3nm thickness, and the nickel0.81Fe0.19 soft-magnetism film 107 of 15nm thickness as 2nd ferromagnetic layer instead of the bilayer film of the CoFe film of 3nm thickness, and the nickel0.81Fe0.19 soft-magnetism film of 15nm thickness, it is the same as the process of drawing 4 . With this element, magnetic-reluctance rate of change is 10.0%, and improves substantially compared with 5.9% obtained with the structure which does not insert the Fe film 106. Moreover, the coercive force of a free layer was 1.2Oe(s), and even if it measured it with the case where the Fe film 106 is not inserted, it was the increment in 1 or less Oe. Thus, magnetic-reluctance rate of change has been improved substantially, keeping the coercive force of a free layer small as 2nd ferromagnetic layer 108 which constitutes a free layer by considering as a bilayer configuration of ultra-thin Fe film and nickel0.81Fe0.19 film called 3nm of thickness. even if this magnetic-reluctance rate of change makes cementation current density increase -- 104 A/cm2 ****** -- private seals were completely changeless.

[0039] Although nickel0.81Fe0.19 film is used as 1st ferromagnetic layer which constitutes the fixed bed from this example, in addition even if it uses the bilayer film of Fe film or nickel0.81Fe0.19 film, and ultra-thin Fe film in the way of thinking same with having been shown in examples 2 and 3, it cannot be overemphasized that the same effect is acquired.

[0040]

[Example 5] Next, the 5th example of this invention is explained to details with reference to a drawing.

[0041] As the basic structure of the magneto-resistive effect element of this invention is shown in drawing 11 The buffer layer 112 which consists of a bilayer film of Ta film of 5nm thickness and nickel0.81Fe0.19 film of 5nm thickness is minded on the Si substrate 111 which oxidized the front face thermally. The 1st ferromagnetic layer 114 which consists of a NiMnSb film with an antiferromagnetism layer [113] and a thickness of 10nm which consists of a FeMn film of formed 15nm thickness, and the tunnel barrier layer 115 which consists of aluminum203 film on it are minded further. It consists of the 2nd ferromagnetic layer 118 which consists of a formed bilayer film of the NiMnSb film 116 with a thickness of 3nm and the nickel0.81Fe0.19 soft-magnetism film 117 with a thickness of 15nm.

[0042] If the manufacture method of this magneto-resistive effect element removes using a NiMnSb film instead of nickel0.81Fe0.19 film as 1st ferromagnetic layer, and using the bilayer film of the NiMnSb film 116 and the nickel0.81Fe0.19 soft-magnetism film 117 as 2nd ferromagnetic layer instead of the bilayer film of a CoFe film and a nickel0.81Fe0.19 soft-magnetism film, it is the same as the process of drawing 4 . With this element, magnetic-reluctance rate of change is 21.3%, and has improved substantially compared with the case where nickel0.81Fe0.19 film is used as 1st ferromagnetic layer. On the other hand, the coercive force of a free layer became large somewhat with 2.6Oe(s). Thus, magnetic-reluctance rate of change has been improved substantially, keeping the coercive force of a free layer to some extent small as 2nd ferromagnetic layer 118 which constitutes a free layer by considering as a bilayer configuration of an ultra-thin NiMnSb film and nickel0.81Fe0.19 film called 3nm of thickness, and using a NiMnSb film as 1st ferromagnetic layer which constitutes the fixed bed further. even if this magnetic-reluctance rate of change makes cementation current density increase -- 104 A/cm2 ****** -- private seals were completely changeless.

[0043] Although the NiMnSb film is used as first ferromagnetic layer which constitutes the fixed bed from this example, in addition even if it uses the bilayer film of nickel0.81Fe0.19 film or nickel0.81Fe0.19 film, and an ultra-thin NiMnSb film in the way of thinking same with having been shown in examples 1 and 3, it cannot be overemphasized that the same effect is acquired.

[0044]

[Effect of the Invention] If the structure of this invention is used, the magneto-resistive effect element which can moreover detect a signal magnetic field to stability by high sensitivity is obtained, and the application to the high density magnetic head, magnetic memory, etc. is also possible. Moreover, if the manufacture method of this invention is used, the tunnel barrier layer of the high quality equipped with resistance required for device application and cementation current density can be formed with a sufficient controllability.

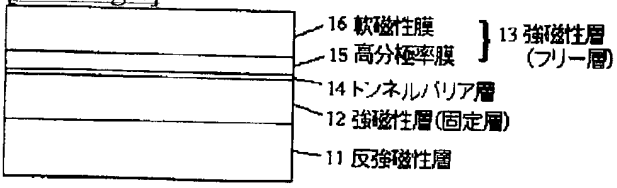
[Translation done.]

* NOTICES *

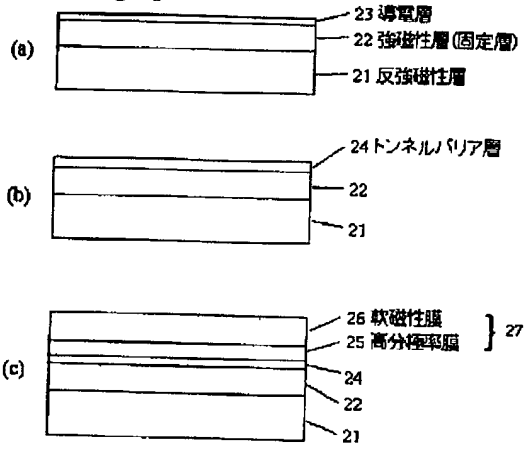
1.This document has been translated by computer. So the translation may not reflect the original precisely.
2.**** shows the word which can not be translated.
3.In the drawings, any words are not translated.

DRAWINGS

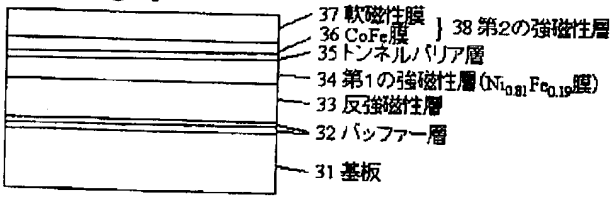
[Drawing 1]



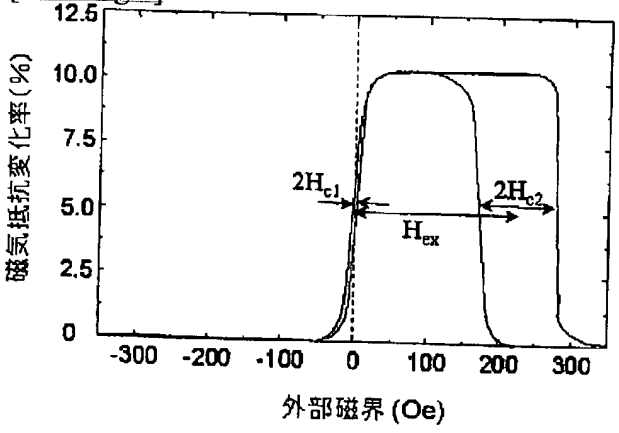
[Drawing 2]



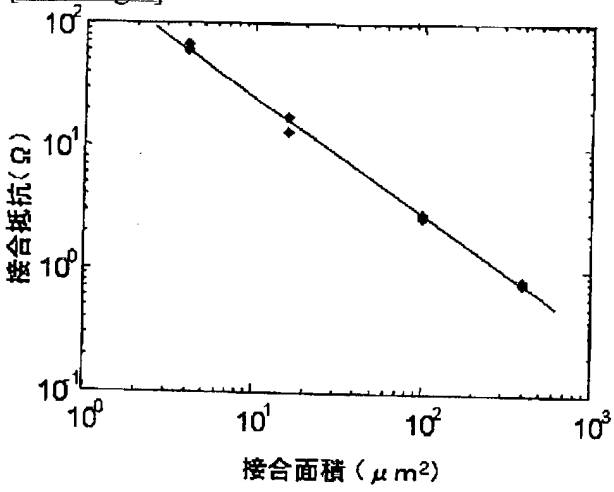
[Drawing 3]



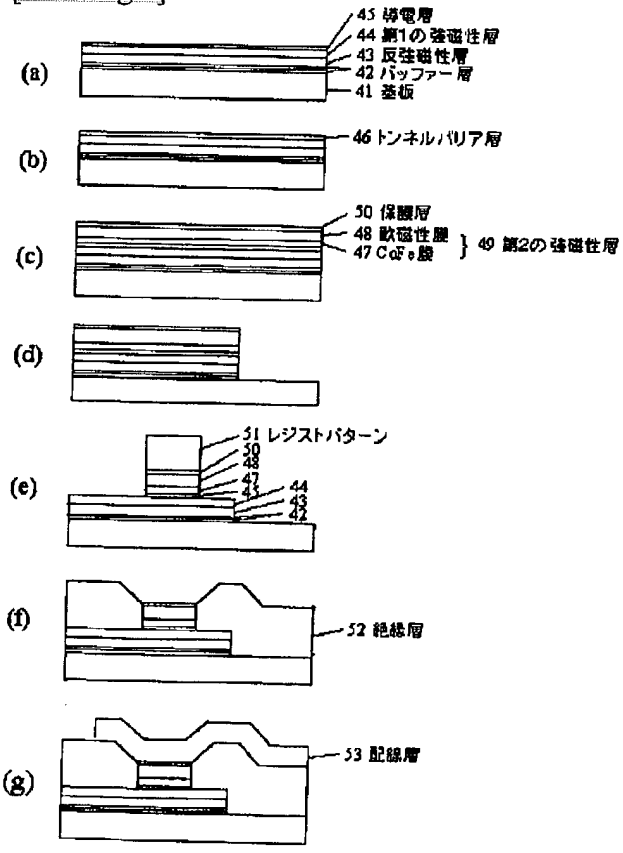
[Drawing 5]



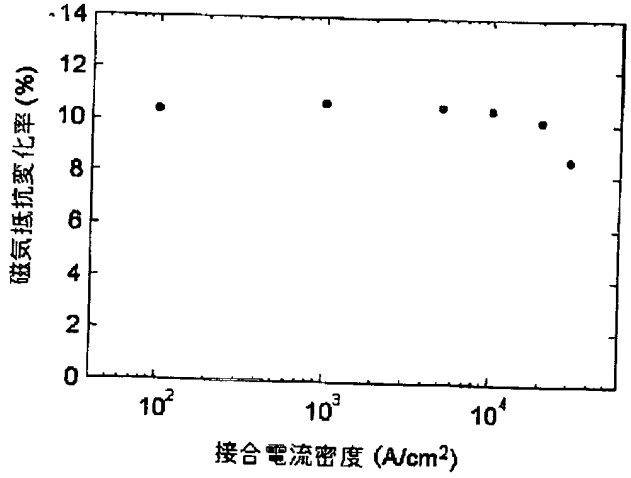
[Drawing 6]



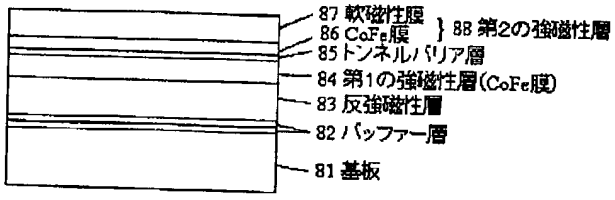
[Drawing 4]



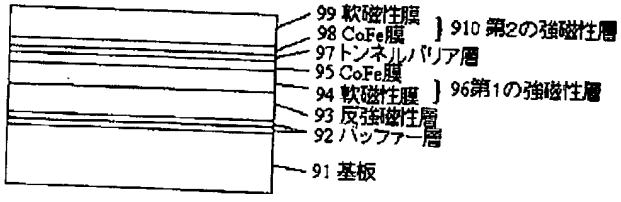
[Drawing 7]



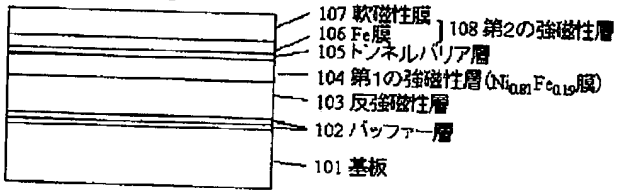
[Drawing 8]



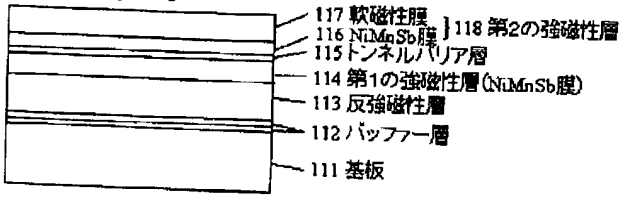
[Drawing 9]



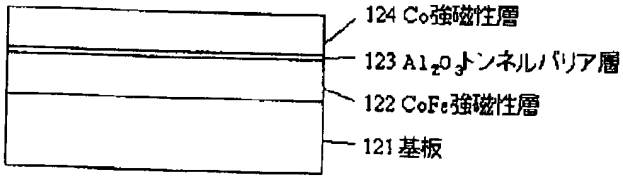
[Drawing 10]



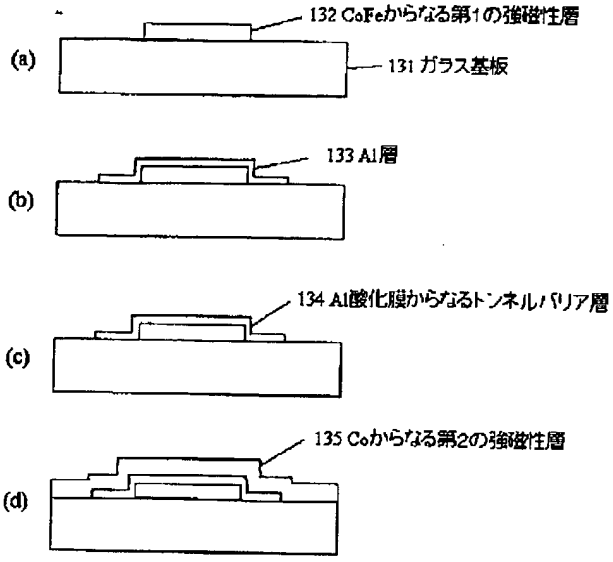
[Drawing 11]



[Drawing 12]



[Drawing 13]



[Translation done.]